

MOBILE STATION ASSISTED TIMING SYNCHRONIZATION IN A CDMA COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to communication systems. More particularly, the present invention relates to a novel and improved method and apparatus for synchronizing a base station by means of signals transmitted from a mobile station which is concurrently in communication with a synchronized base station.

II. Description of the Related Art

The use of code division multiple access (CDMA) modulation techniques is but one of several techniques for facilitating communications in which a large number of system users are present. Although other techniques, such as time division multiple access (TDMA), frequency division multiple access (FDMA) and AM modulation schemes such as amplitude companded single sideband (ACSSB) are known, CDMA has significant advantages over these other modulation techniques. The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Pat. No. 4,901,307, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS" and U.S. Pat. No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM", both of which are assigned to the assignee of the present invention and are incorporated by reference. The method for providing CDMA mobile communications was standardized in the United States by the Telecommunications Industry Association in TIA/EIA/IS-95-A entitled "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System", referred to herein as IS-95.

In the just mentioned patents, a multiple access technique is disclosed in which a large number of mobile station users, each having a transceiver, communicate through satellite repeaters or terrestrial base stations (also known as cell base stations or cell-sites) using code division multiple access (CDMA) spread spectrum communication signals. By using CDMA communications, the frequency spectrum can be reused multiple times thus permitting an increase in system user capacity. The use of CDMA techniques result in much higher spectral efficiency than can be achieved using other multiple access techniques.

A method for simultaneously demodulating data that has traveled along different propagation paths from one base station and for simultaneously demodulating data redundantly provided from more than one base station is disclosed in U.S. Pat. No. 5,109,390 (the '390 patent), entitled "DIVERSITY RECEIVER IN A CDMA CELLULAR COMMUNICATION SYSTEM", assigned to the assignee of the present invention and incorporated by reference herein. In the '390 patent, the separately demodulated signals are combined to provide an estimate of the transmitted data which has higher reliability than the data demodulated by any one path or from any one base station.

Handoffs can generally be divided into two categories—hard handoffs and soft handoffs. In a hard handoff, when a mobile station leaves an origination base station and enters a destination base station, the mobile station breaks its communication link with the origination base station and thereafter establishes a new communication link with the destination base station. In soft handoff, the mobile station

completes a communication link with the destination base station prior to breaking its communication link with the origination base station. Thus, in soft handoff, the mobile station is redundantly in communication with both the origination base station and the destination base station for some period of time.

Soft handoffs are far less likely to drop calls than hard handoffs. In addition, when a mobile station travels near the coverage boundary of a base station, it may make repeated handoff requests in response to small changes in the environment. This problem, referred to as ping-ponging, is also greatly lessened by soft handoff. The process for performing soft handoff is described in detail in U.S. Pat. No. 5,101,501, entitled "METHOD AND SYSTEM FOR PROVIDING A SOFT HANDOFF IN COMMUNICATIONS IN A CDMA CELLULAR TELEPHONE SYSTEM" assigned to the assignee of the present invention and incorporated by reference herein.

An improved soft handoff technique is disclosed in U.S. Pat. No. 5,267,261, entitled "MOBILE STATION ASSISTED SOFT HANDOFF IN A CDMA CELLULAR COMMUNICATIONS SYSTEM", which is assigned to the assignee of the present invention and incorporated by reference herein. In the system of the '261 patent, the soft handoff process is improved by measuring the strength of "pilot" signals transmitted by each base station at the mobile station. These pilot strength measurements are of assistance in the soft handoff process by facilitating identification of viable base station handoff candidates.

The base station candidates can be divided into four sets. The first set, referred to as the Active Set, comprises base stations which are currently in communication with the mobile station. The second set, referred to as the Candidate Set, comprises base stations whose signals have been determined to be of sufficient strength to be of use to the mobile station but are not currently being used. Base stations are added to the candidate set when their measured pilot energy exceeds a predetermined threshold T_{ADD} . The third set is the set of base stations which are in the vicinity of the mobile station (and which are not included in the Active Set or the Candidate Set). And the fourth set is the Remaining Set which consists of all other base stations.

In IS-95, a base station candidate is characterized by the phase offset of the pseudonoise (PN) sequence of its pilot channel. When the mobile station searches to determine the strength of the pilot signal from a candidate base station it performs a correlation operation wherein the filtered received signal is correlated to a set of PN offset hypotheses. The method and apparatus for performing the correlation operation is described in detail in co-pending U.S. patent application Ser. No. 08/687,694, filed on Jul. 26, 1996, entitled "METHOD AND APPARATUS FOR PERFORMING SEARCH ACQUISITION IN A CDMA COMMUNICATION SYSTEM", which is assigned to the assignee of the present invention and incorporated by reference herein.

The propagation delay between the base station and the mobile station is not known. This unknown delay produces and unknown shift in the PN codes. The searching process attempts to determine the unknown shift in the PN codes. To do this, the mobile station shifts in time the output of its searcher PN code generators. The range of the search shift is called the search window. The search window is centered about a PN shift hypothesis. A base station transmits to the mobile station a message indicating the PN offsets of base station pilots in its physical proximity. The mobile station will center its search window around the PN offset hypothesis.